CEPC ECAL R&D Status

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On behalf of CEPC calorimeter working group

Outline

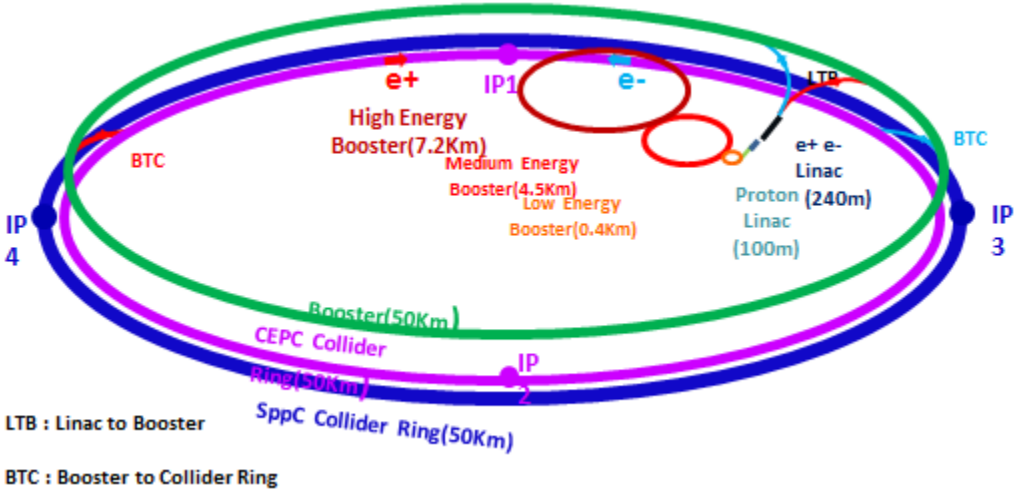
- Motivation
- CEPC ECAL
  - Sensitive Detector
  - Readout Electronics
- Test Results
  - Single layer prototype assembling
  - Cosmic rays test
- Summary

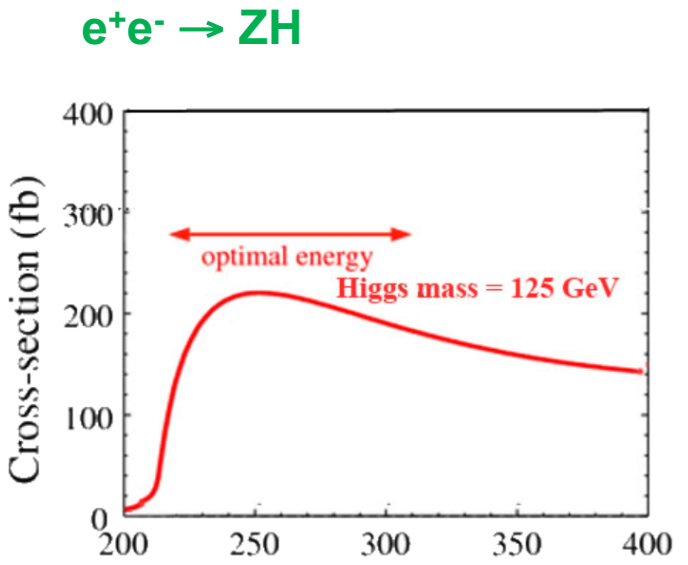
Motivation

Circular Electron Positron Collider (CEPC)

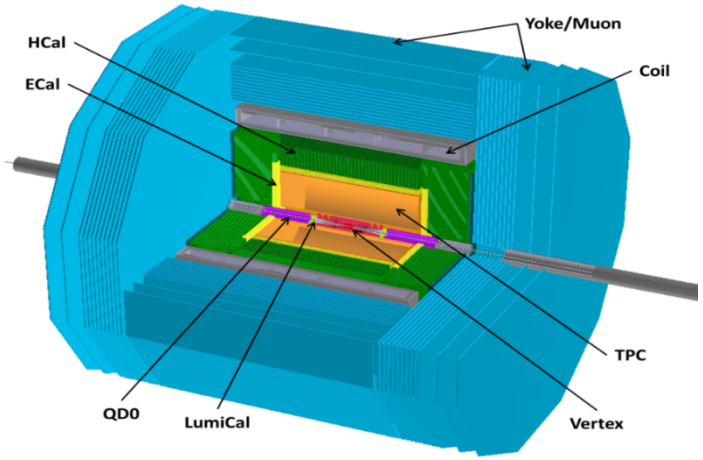
$E_{cm} \approx 240$GeV, luminosity $\sim 2\times10^{34}$ $cm^{-2}s^{-1}$ can also rum at the Z-pole

Precision measurement of the Higgs boson (and the Z boson)





Requirements of CEPC EMCal



- **ILD-like detector with additional considerations.**

Challenges:

- **Momentum:** $\sigma_{1/p} < 5\times10^{-5}\ \mathrm{GeV}^{-1}$
- **Impact parameter:** $\sigma_{r\phi} = 5 \oplus 10/(p\cdot\sin^{\frac{3}{2}}\theta)\ \mu\mathrm{m}$
- **Jet energy:** $\frac{\sigma_E}{E} \approx 3-4\%$

- The Particle Flow Algorithm (PFA) calorimeter concept was proposed
  - High granularity
  - Good track finding
  - Good energy resolution

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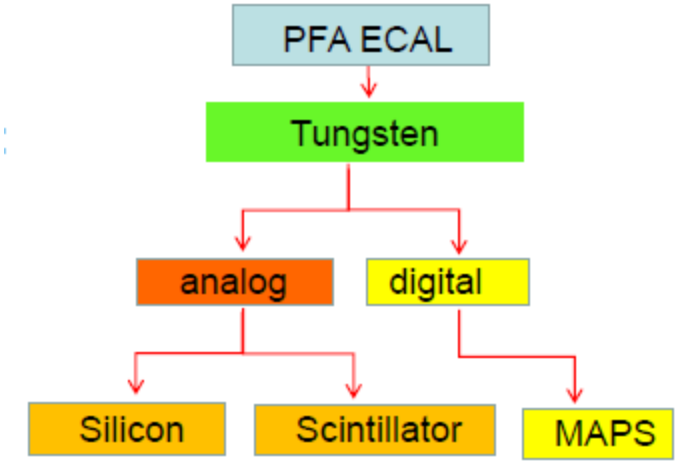
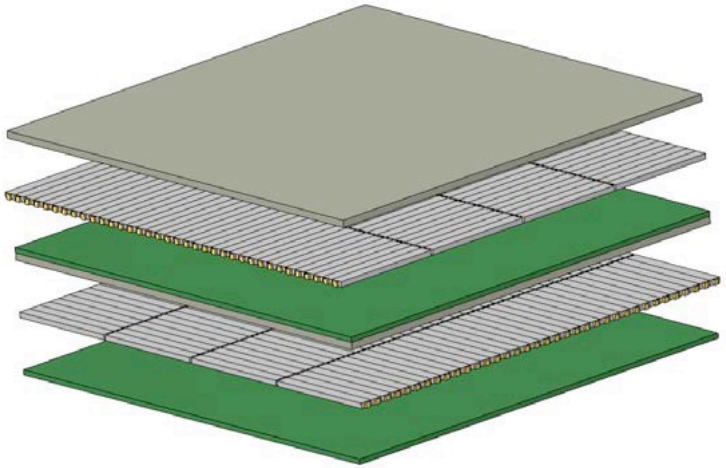
CEPC ECAL

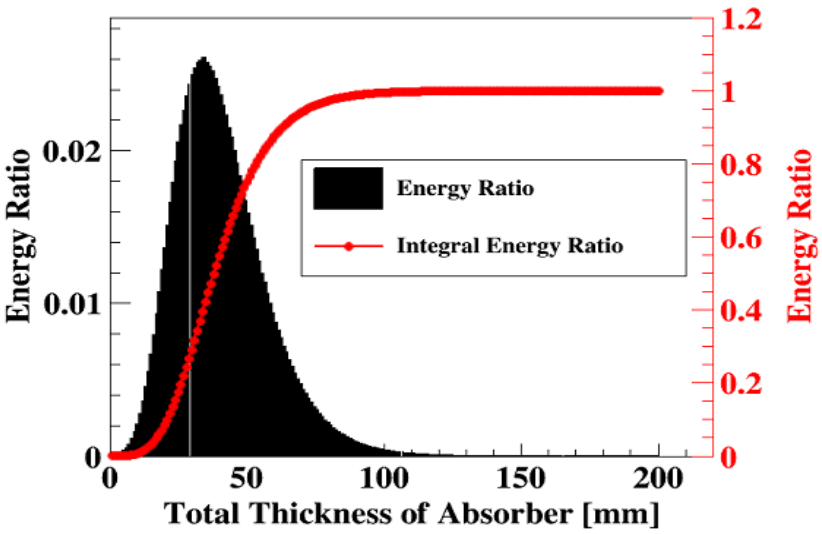
- Sampling Calorimeter
  - Sandwich structure
  - Absorber+SD+Electronics
- Absorber
  - Tungsten
- Sensitive Detector
  - Scintillator+SiPM
- Electronics
  - SPIROC Chip

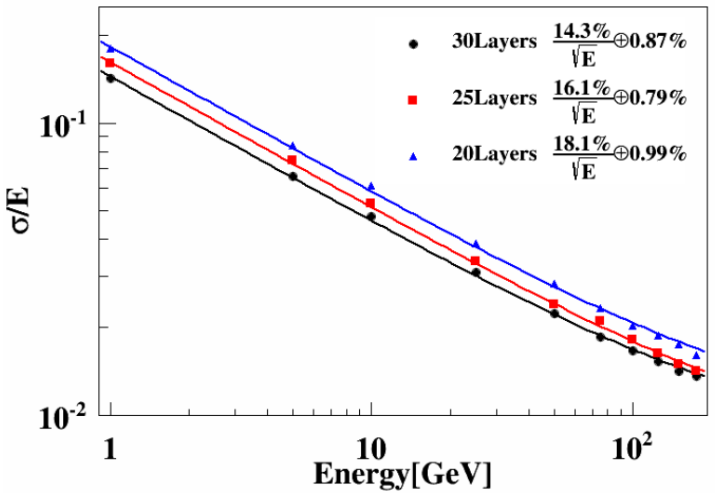


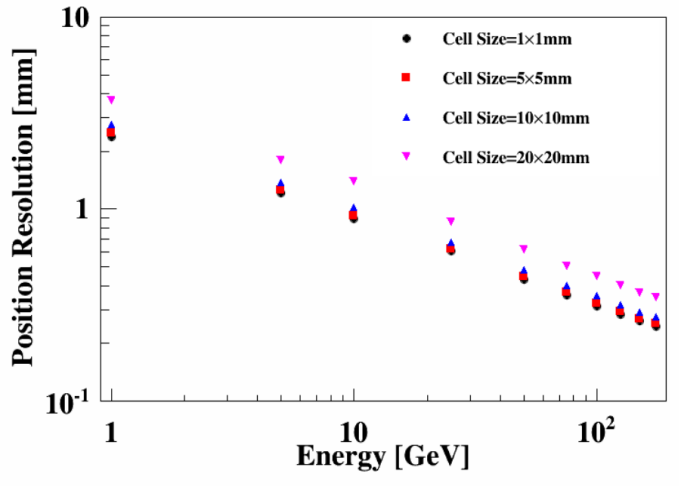


ECAL Optimization I

- Total thickness: 24 X_0
- Sampling number: 30 layers
- Granularity: <10mm*10mm

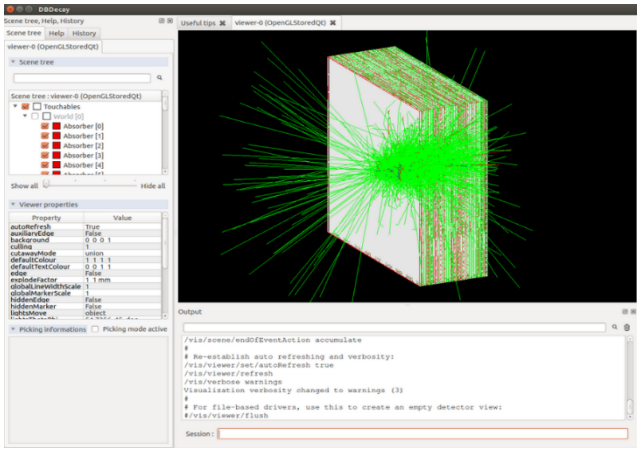


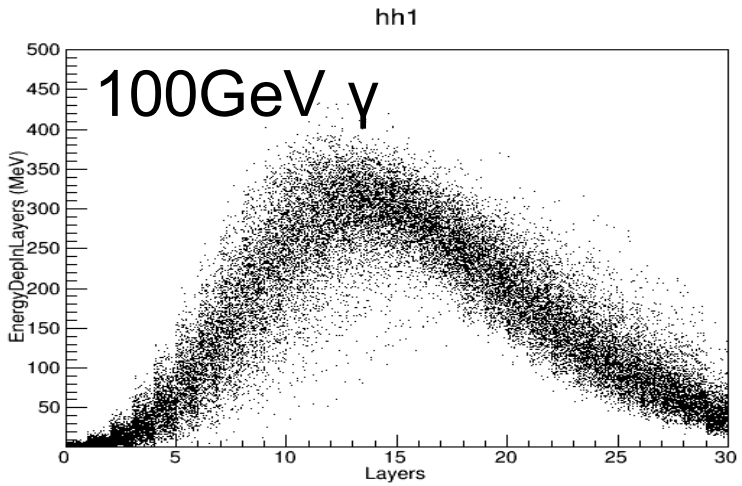




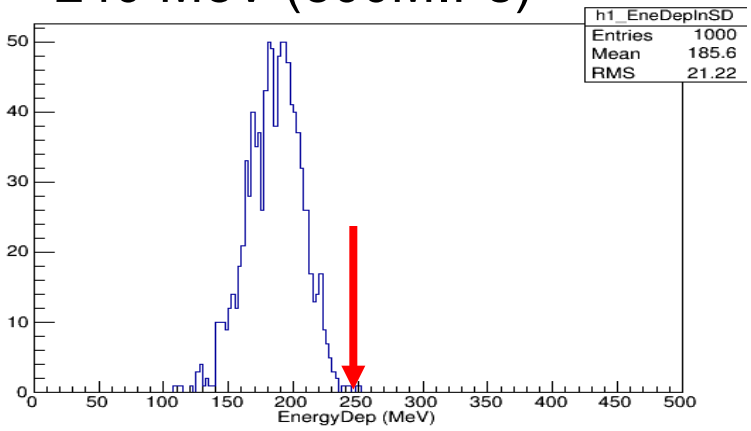
ECAL Optimization II

- Dynamic range of ECAL SD
  - 1MIP – 800 MIPs
- ~10 pe @ 1 MIP
  - SiPM ~10k pixels
- Gain of SiPM:~10^5
  - SPIROC:160fC – 100 pC



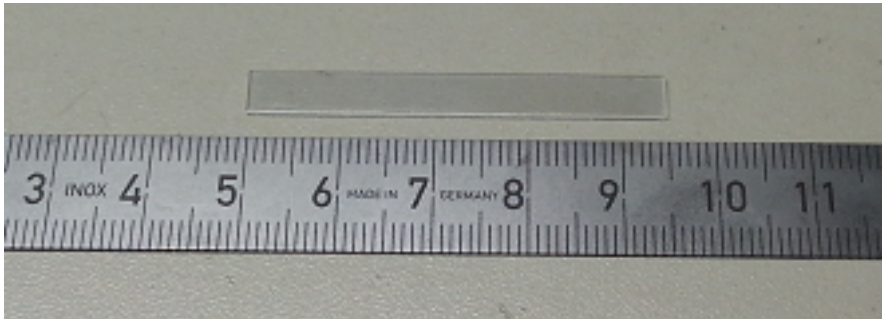


Shower profile in ECAL



Max edep in SD

Elements of ECAL



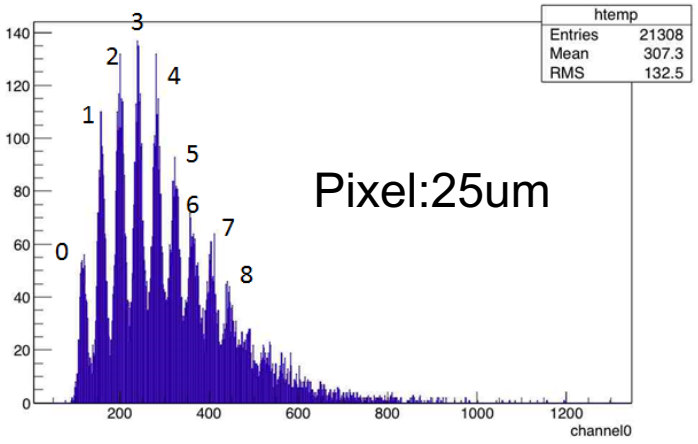
Scintillator （5 mm*45 mm*2 mm）

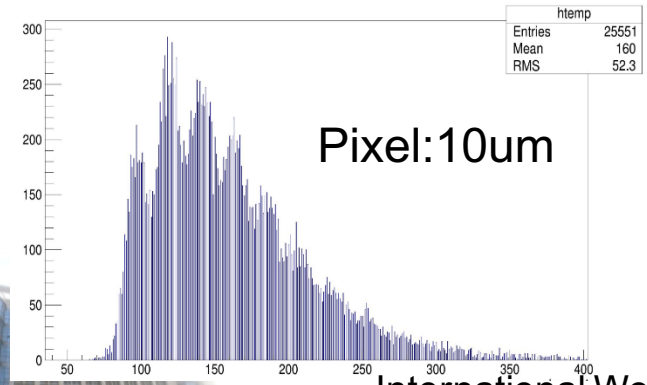
SiPM（1mm＊1mm, 10k pixels）

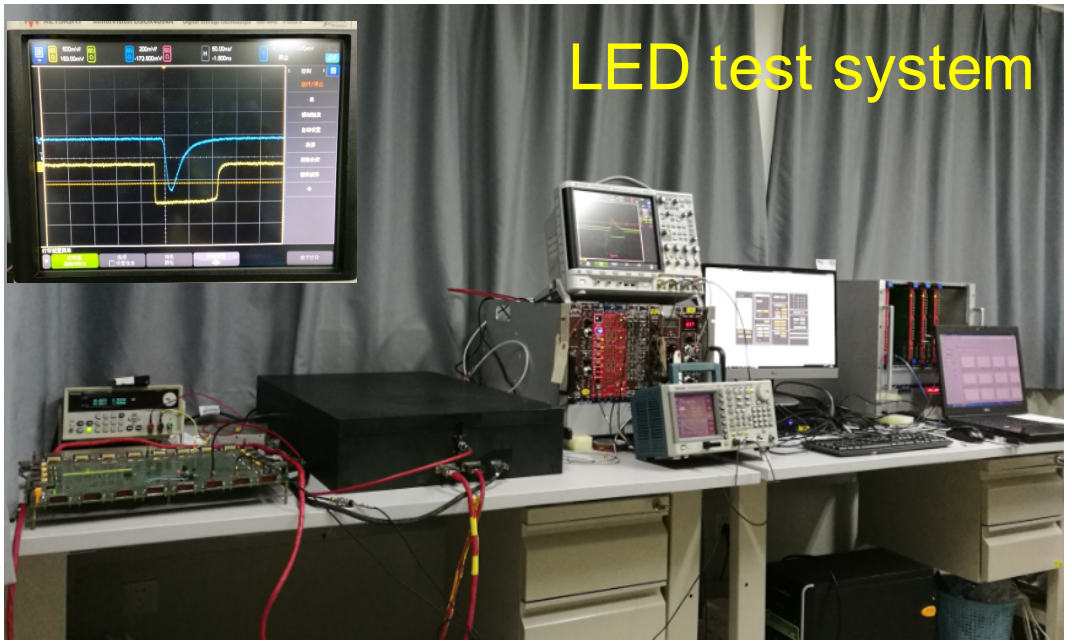
- Dynamic range：~100fC~200pC
- channels：36
- Dead time：2ms
- Polar: positive
- power：8mW/channel

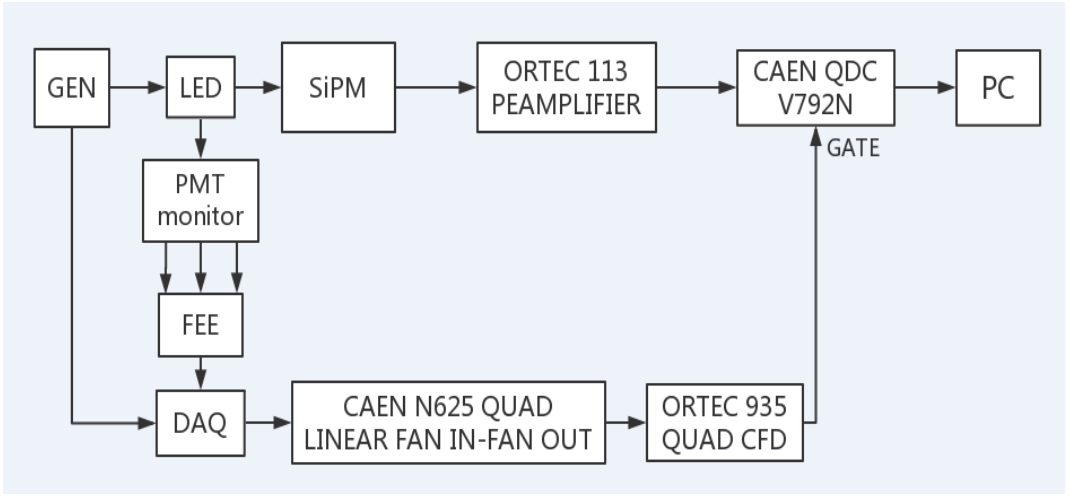
SiPM Test

LED test system was built to test the SiPM dynamic range





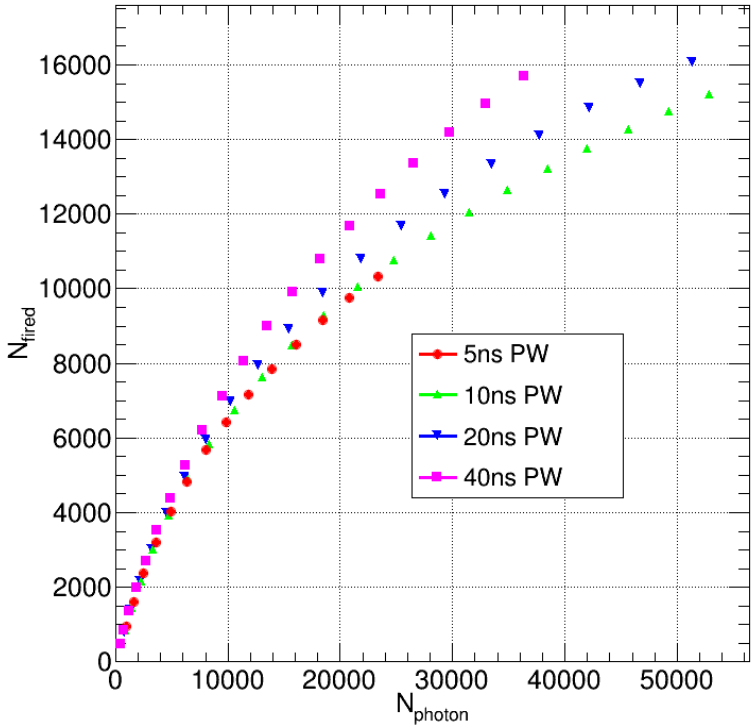




SiPM Test

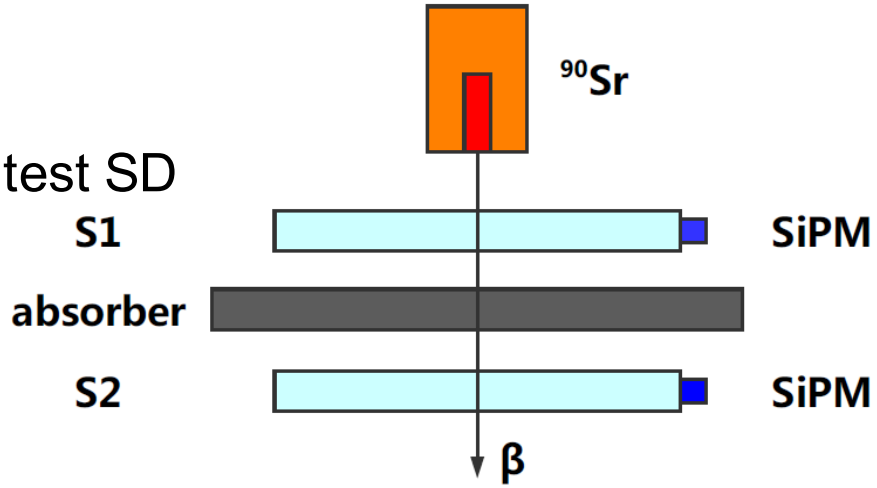
The width of LED light are:5 ns, 10 ns, 20 ns and 40 ns

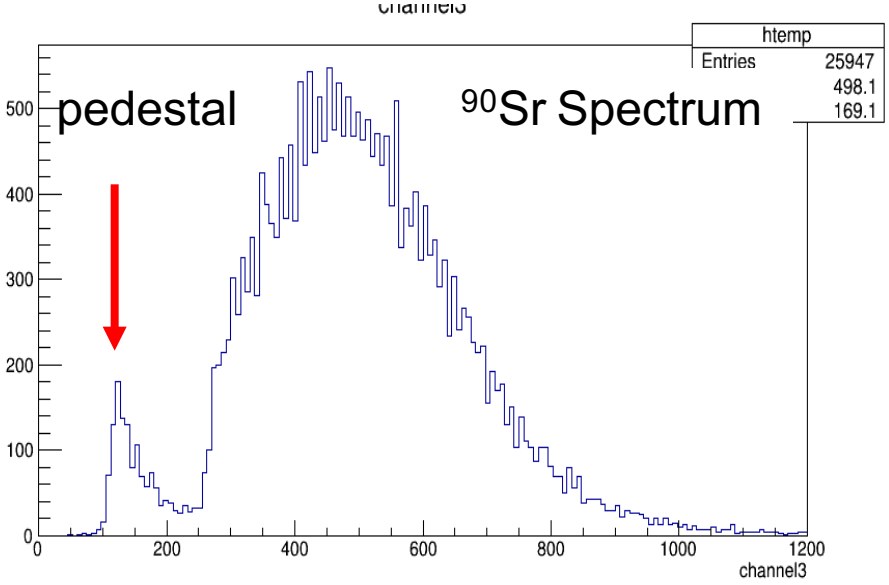
- As the photon width increases, SiPM effective pixels also increase
- SiPM response can be described well with the theoretic formula
- Through correction 10K pixels SiPM dynamic range can up to 16,000 photons with less than 1% error



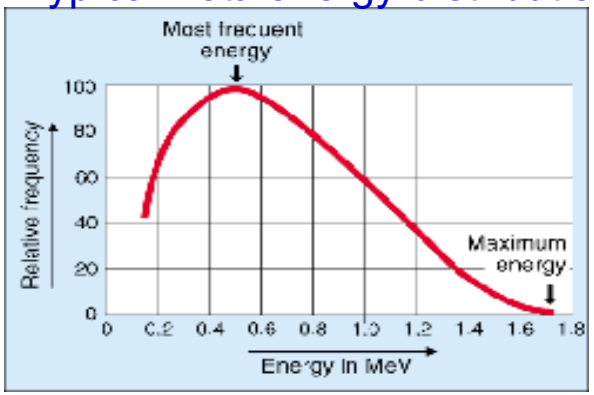
Scintillator Test

- Plastic scintillator
  - Size: 2mm*5mm*45mm
  - “high energy” β-rays as MIPs to test SD

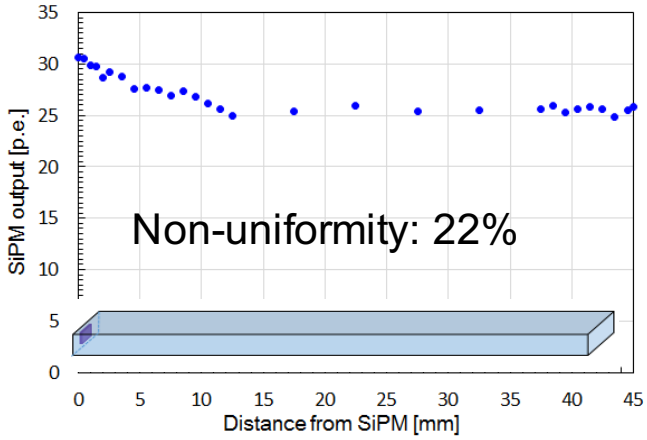


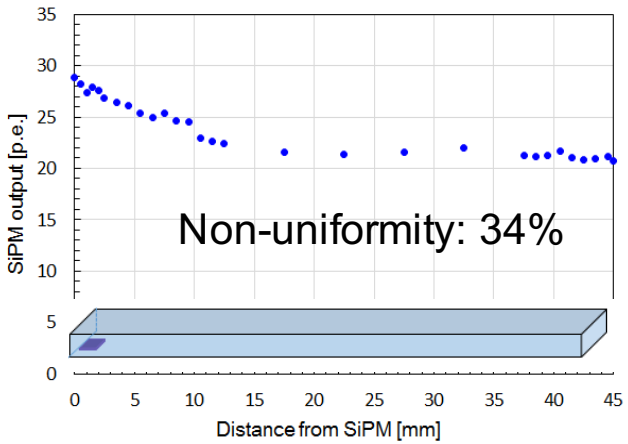


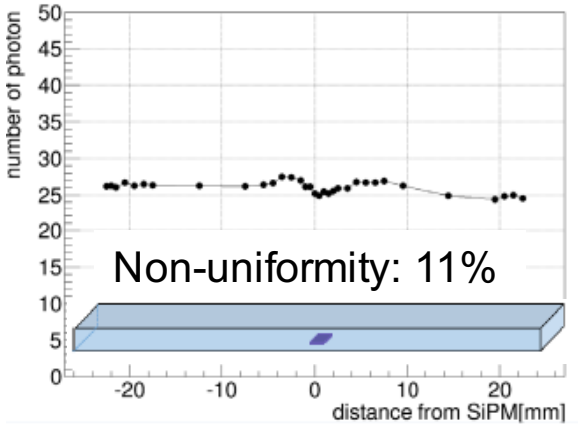
Typical Beta energy distribution



Scintillator coupling mode





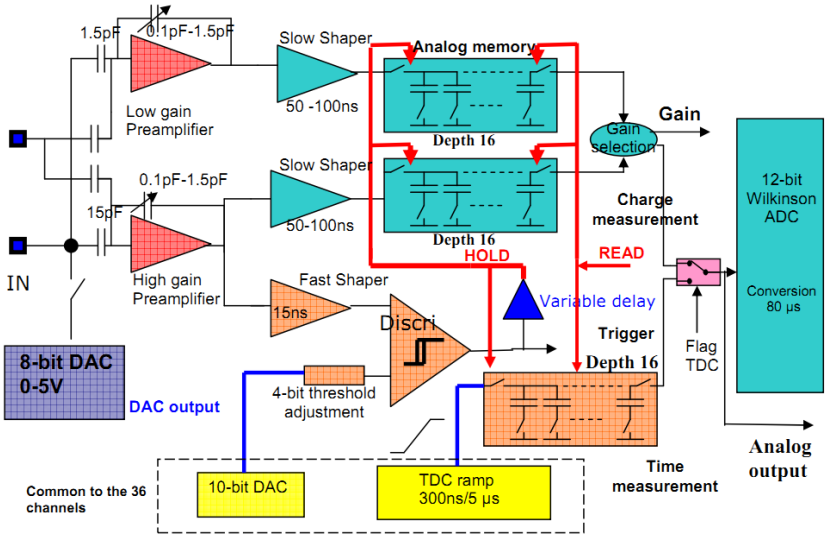


- Three classes coupling mode i.e. side-end, bottom-end and bottom-center
- Light outputs along the length of the scintillator strip is non-uniformity, degrades the energy resolution
- Bottom-center coupling have the minimum non-uniformity
  - Avoiding the dead area between scintillators
  - Simplifying scintillators assembling process
  - Enabling to extend the SiPM area with more pixels

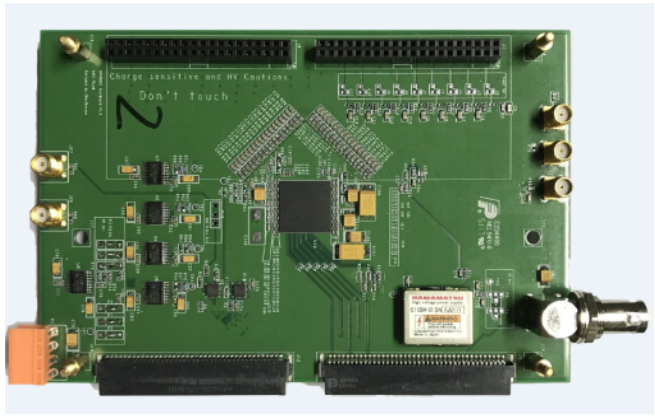
Readout Electronics

- SiPM front-end with **ASIC**

  SPIROC2b/SPIROC2e of 36 channels
- Switched capacitor array store charge measurement
- 12 bits ADC conversion
- Variable Gain due to:
  - adjustable C_f of pre-amplifer
  - R_{load} on the board
  - Shaping time and delay



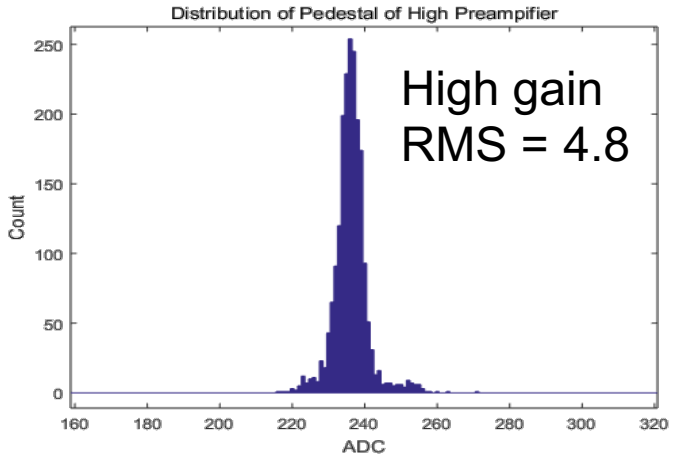
SPIROC2B

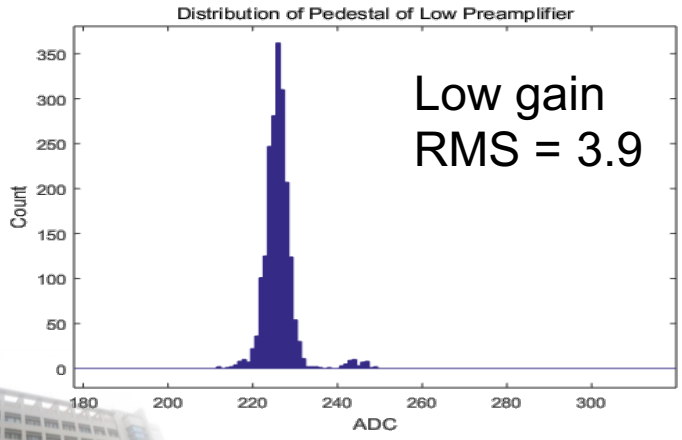


SPIROC2E

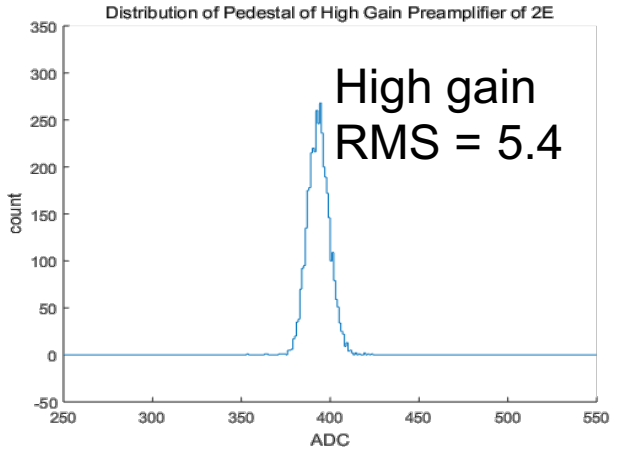
Pedestal of SPIROC2b/2e

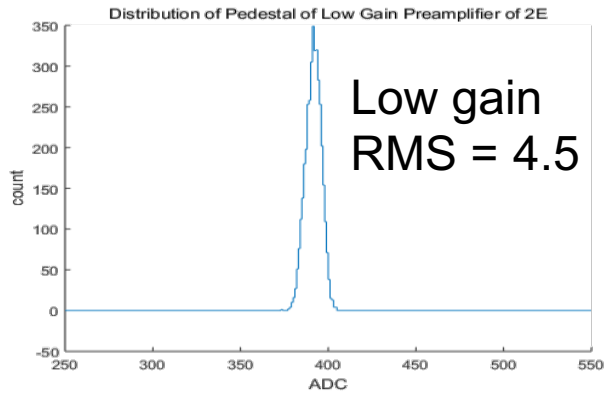
SPIROC2b





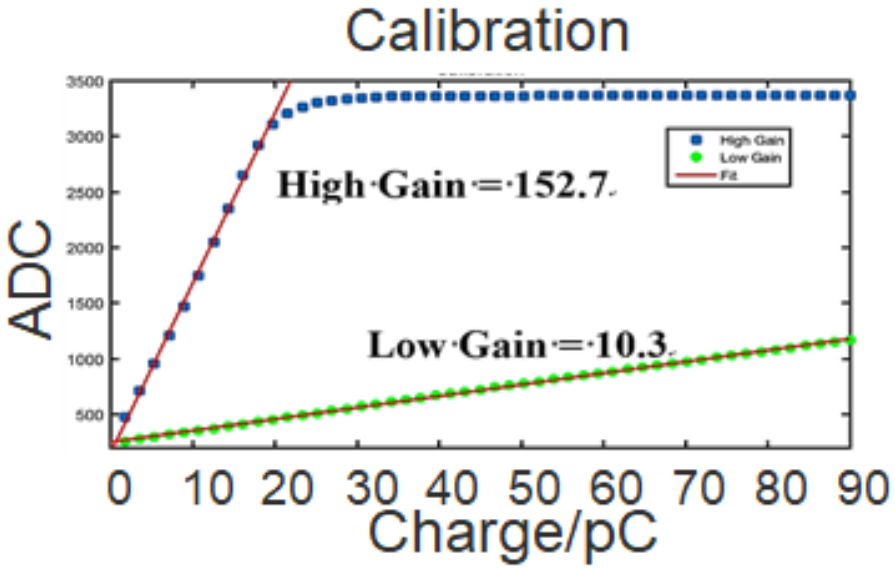
SPIROC2e



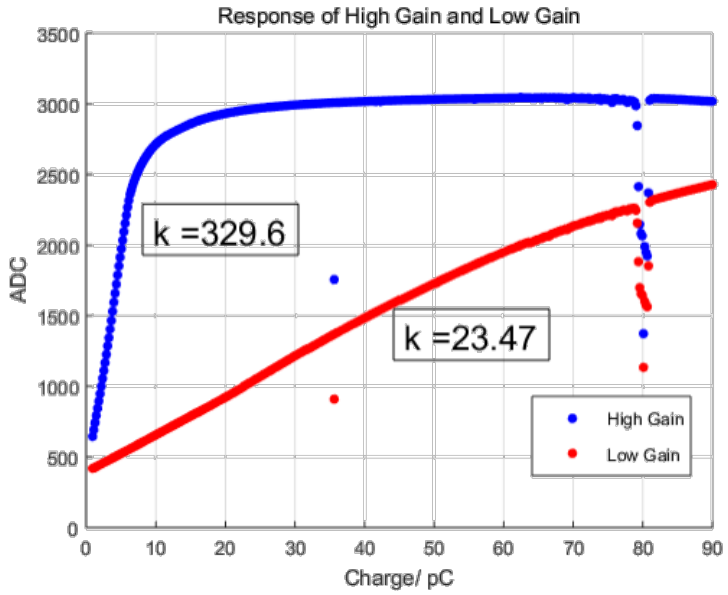


Dynamic range of SPIROC2b/2e

SPIROC2b

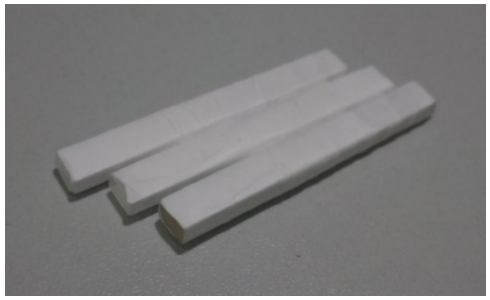


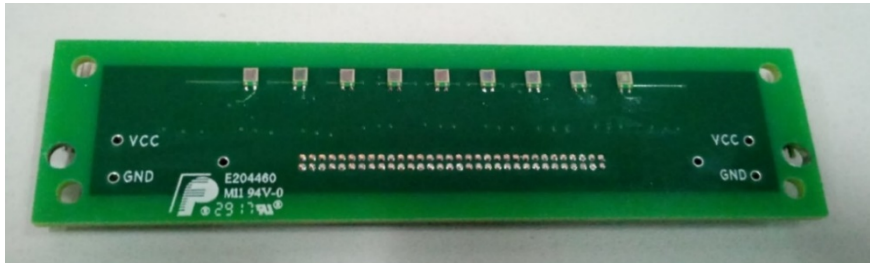
SPIROC2e

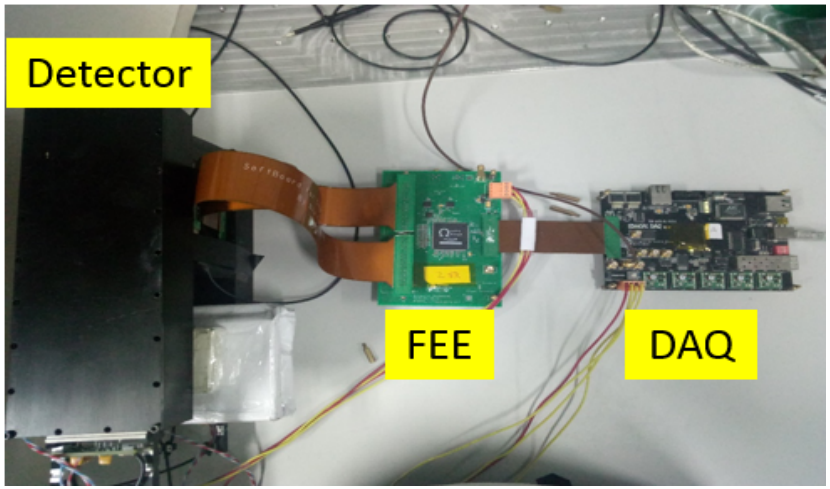


Cosmic Ray Test

- Scintillator coupled with SiPM was tested by cosmic rays
  - Plastic scintillator
    - BC408
- SiPM
  - S12571-010P
  - 1mm*1mm
  - 10k pixels

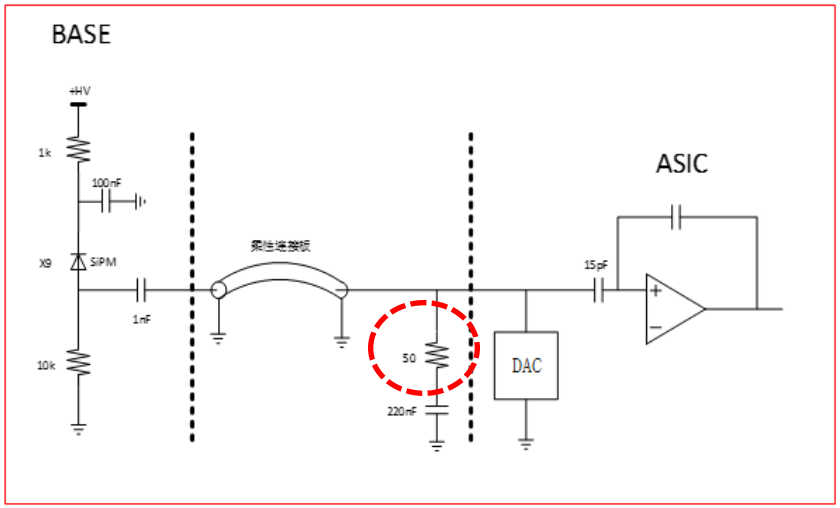




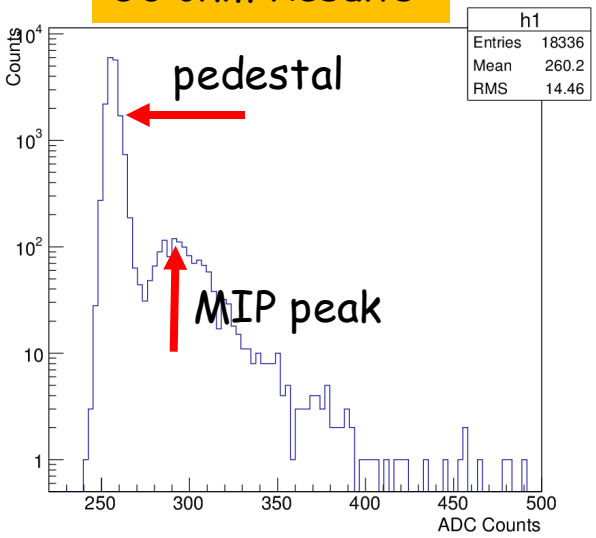


Cosmic ray Results

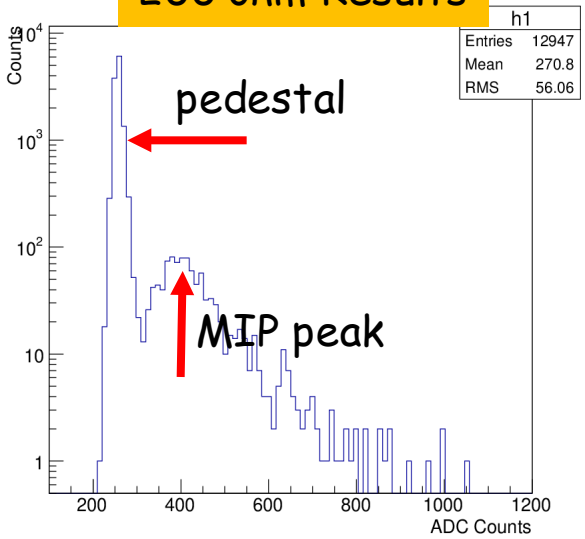
	sigma/ Ch	MIP/Ch	S/N
50ohm	2.7	35.7	13.2
200ohm	6.0	147.2	24.5
1kohm	24.7	389	15.7



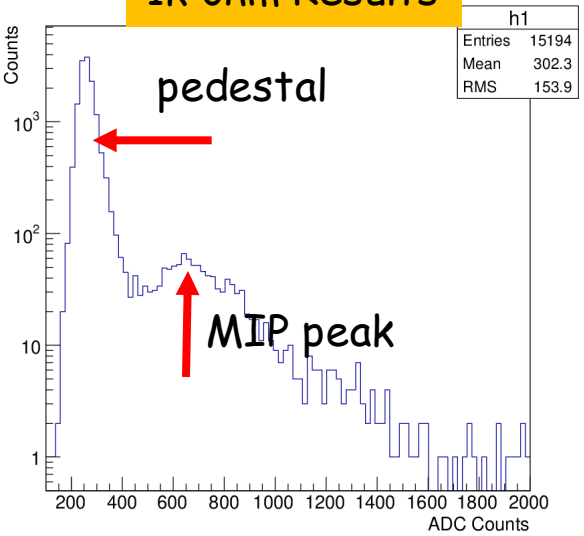
50 ohm Results



200 ohm Results



1k ohm Results



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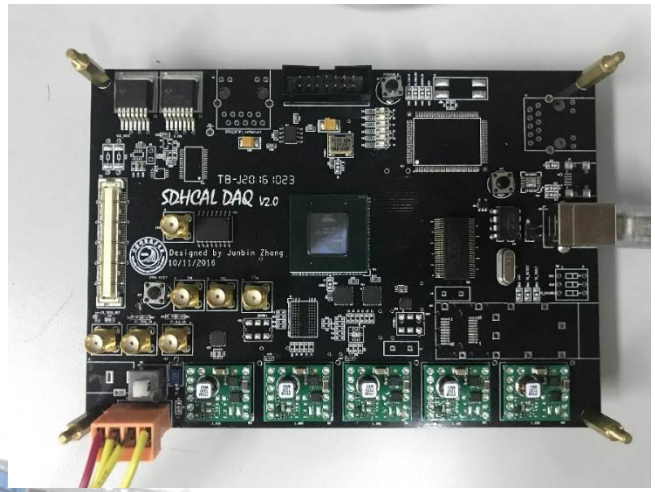
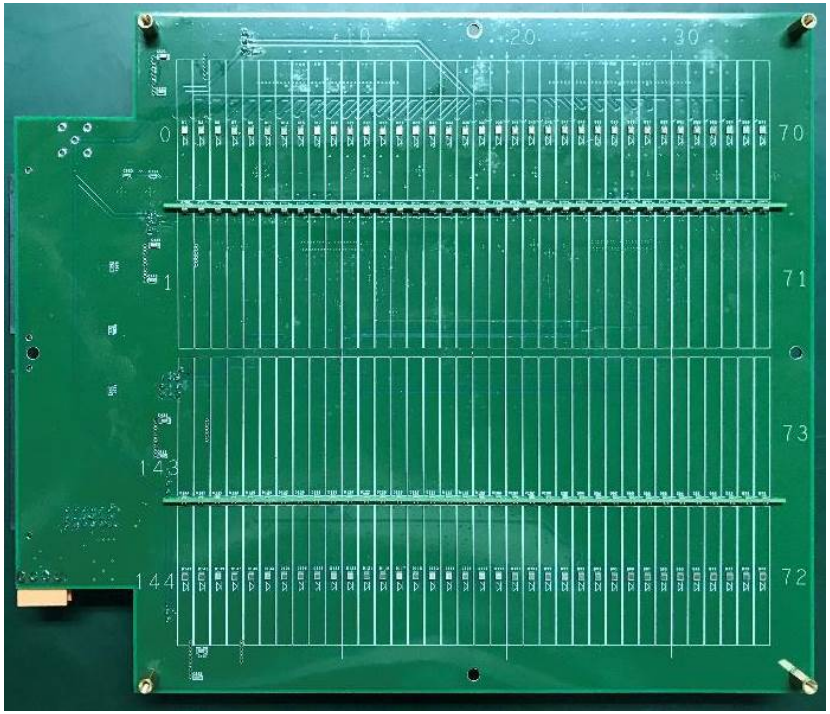
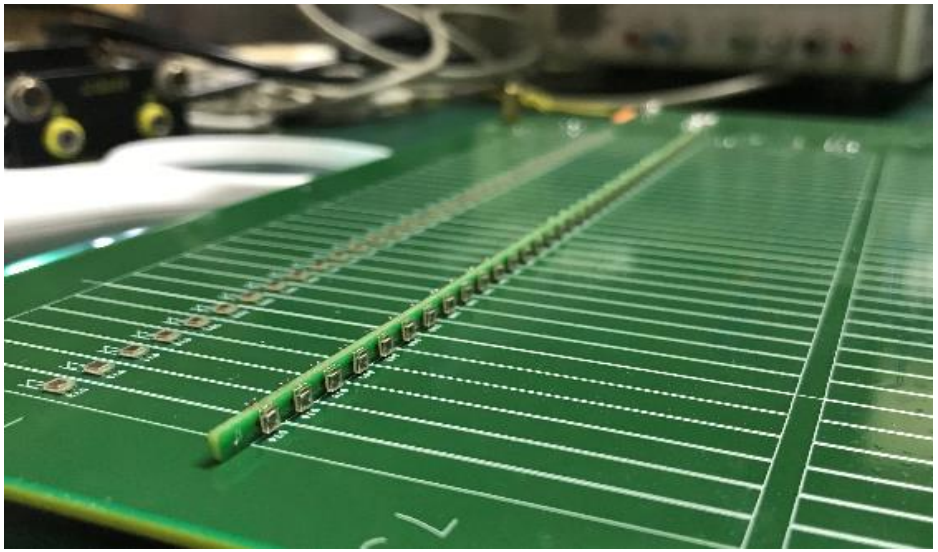
Single Layer Prototype

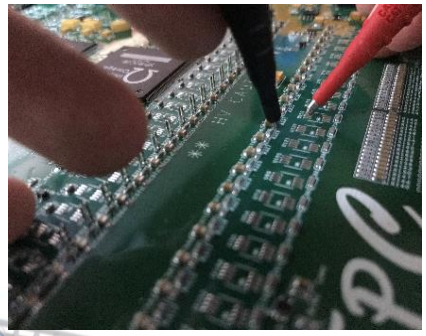
- Front End Board
  - 4 SPIROC2b chips
  - 144 channels
    - SD: BC408,
    - SiPM: S12571-010P
    - Bias HV: C11204-01
- Data Interface Board

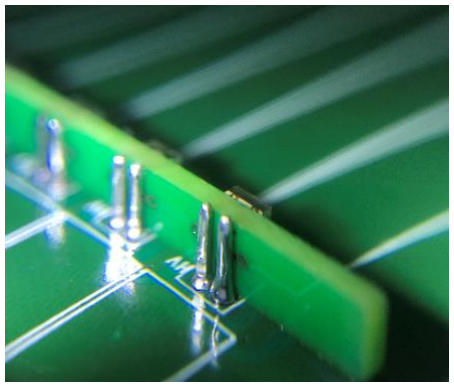


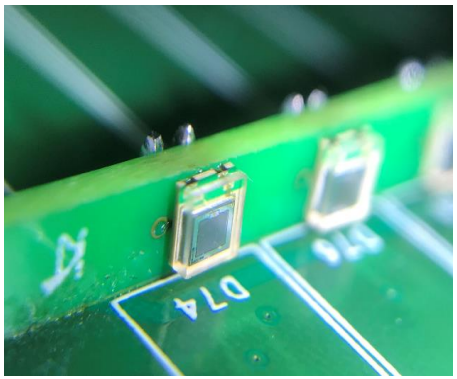
Single Layer Prototype





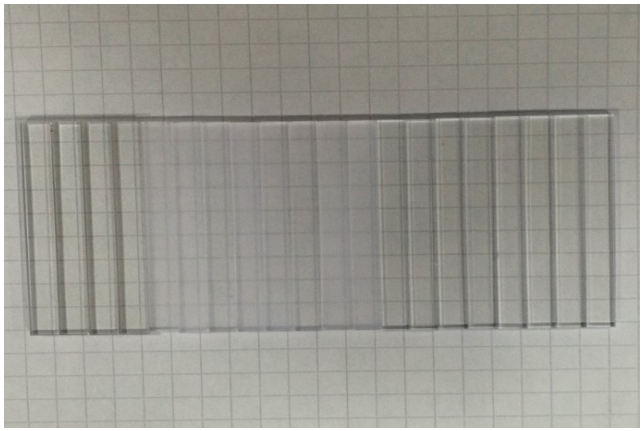


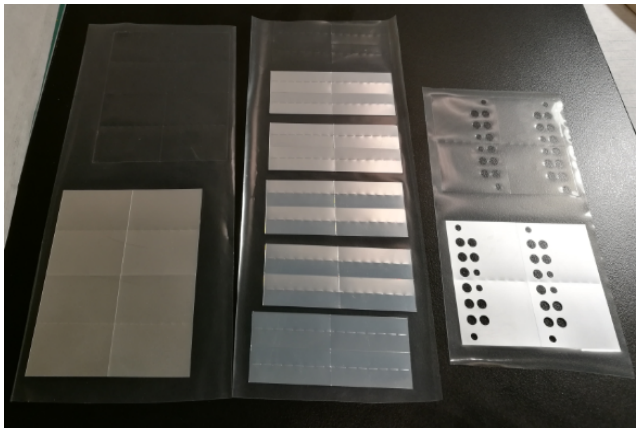


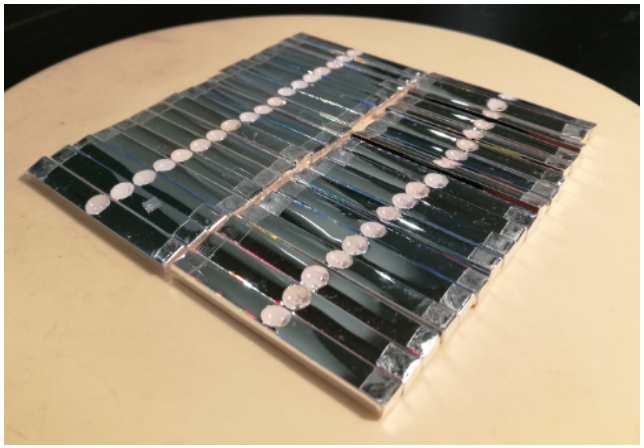


Single Layer Prototype

- Cutting
- Grooving
- Polishing
- Annealing
- Cleaning
- Packing







Single Layer Prototype

Visual inspection

Size measurement

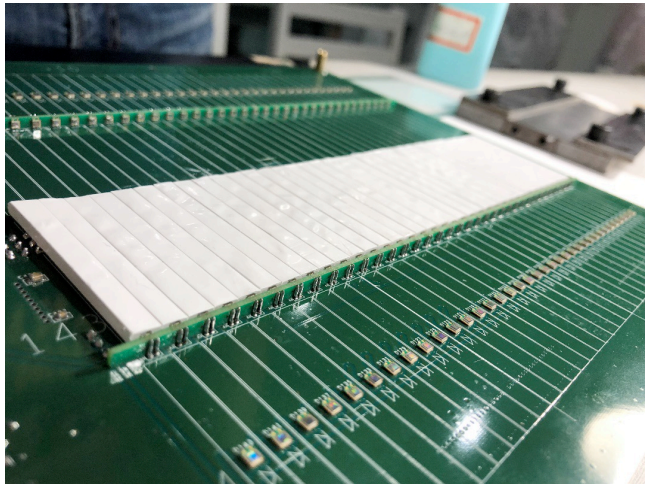
cleaning

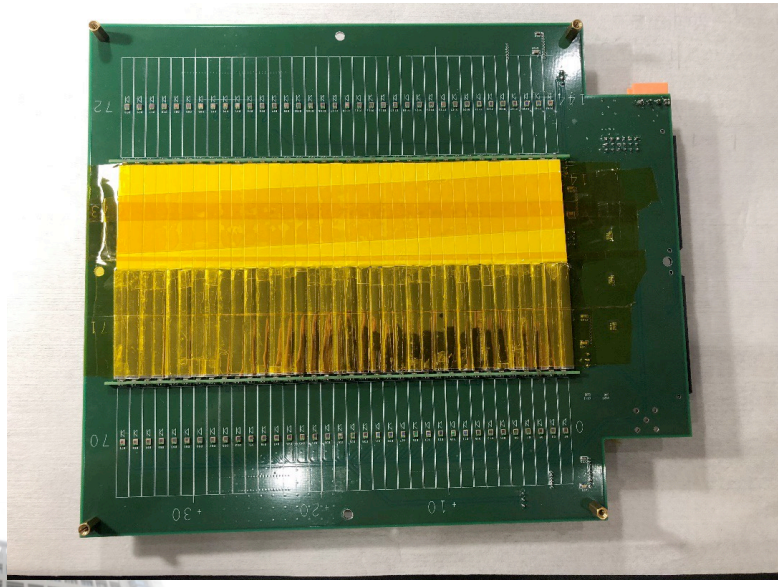
assembling

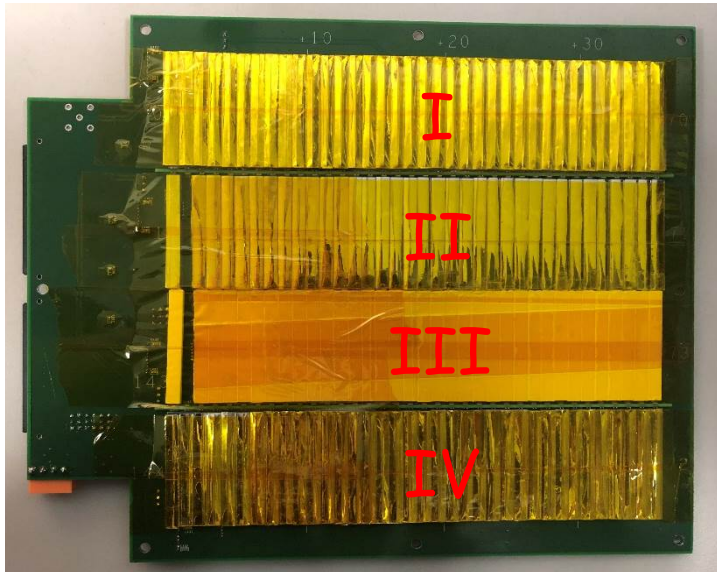
The single layer prototype was assembled in Shanghai Institute of Ceramic (SIC)

Single Layer Prototype

- 144 modules of scintillator strip coupling with SiPM (S12571-010P)
- I and IV: bottom-center embedded coupling mode, wrapped with ESR
- II: Side-end coupling mode scintillators wrapped with ESR
- III: Side-end coupling mode scintillators wrapped with Teflon

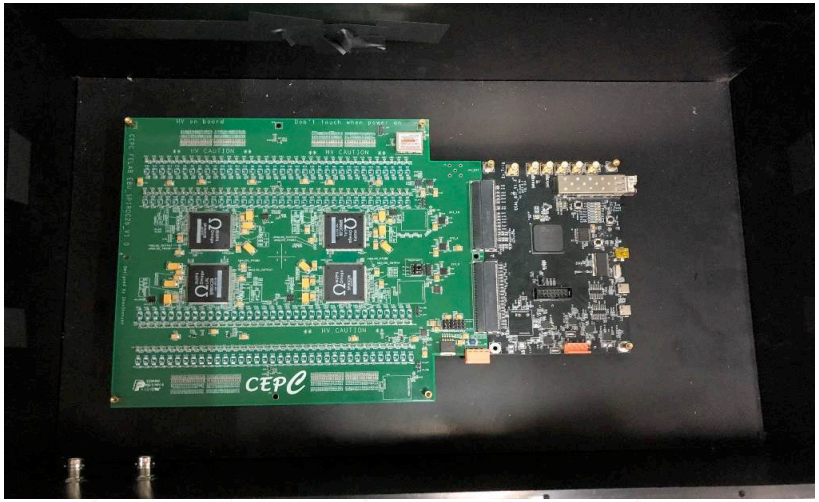


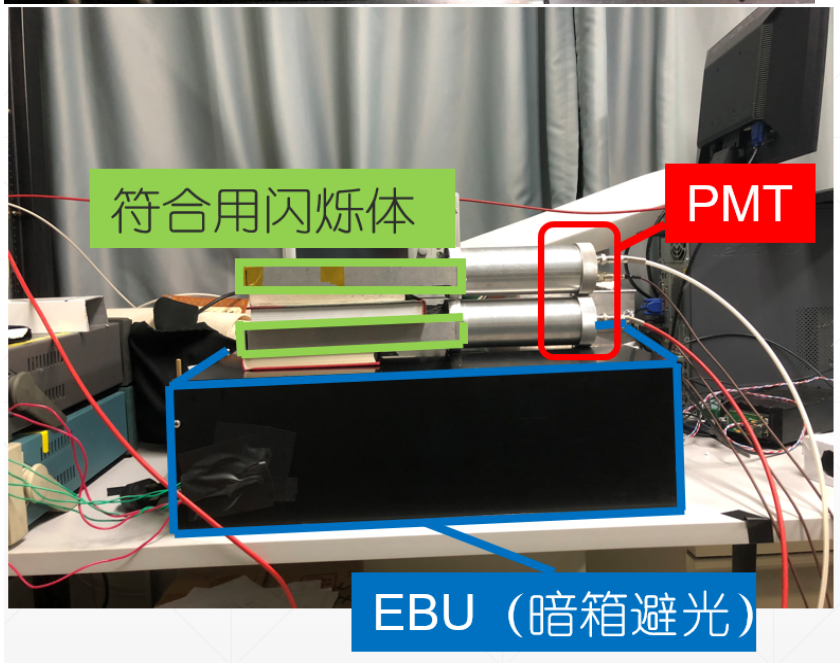




Single Layer Prototype

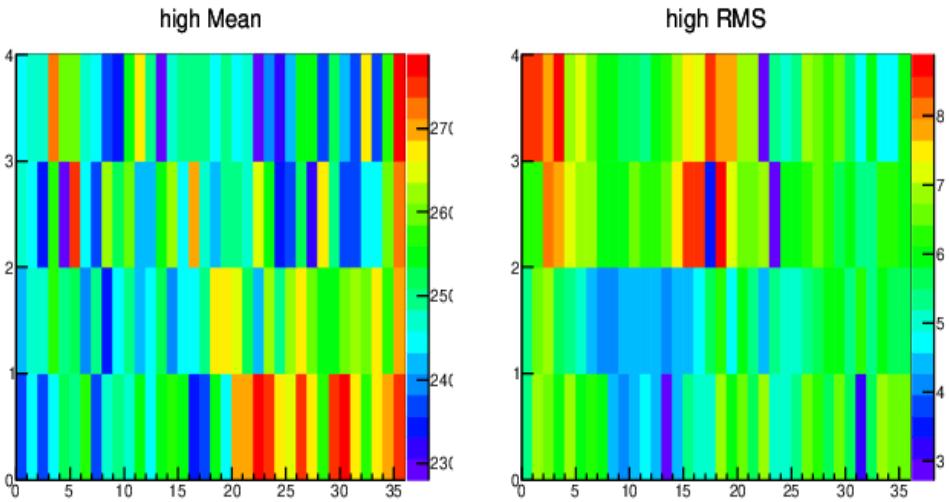
- Cosmic Ray Test
  - The telescope was composed of two plastic scintillators which with size of 20 cm * 20 cm.
  - The FEB and DIF boards were put in the dark box
  - The noise of each channel could be tested and stability could be monitored
  - The response to cosmic ray of each channel could be tested and could be used to evaluate the different wrapped and coupled methods.

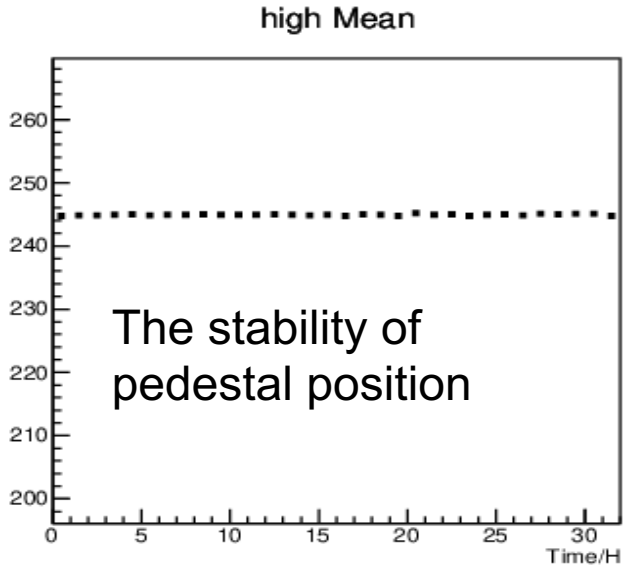


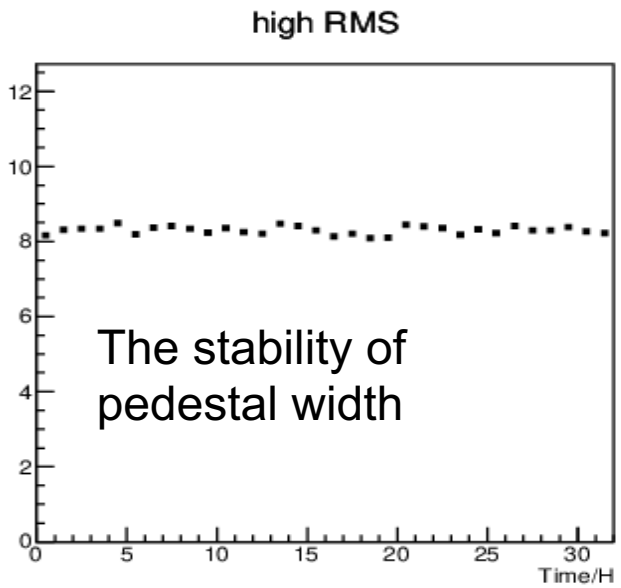


Electronics performance

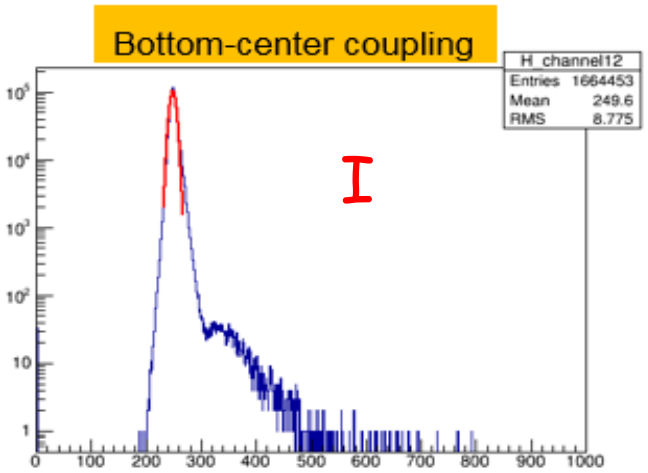
- Working in high gain mode
- SiPM with H.V.
- Long time work stability

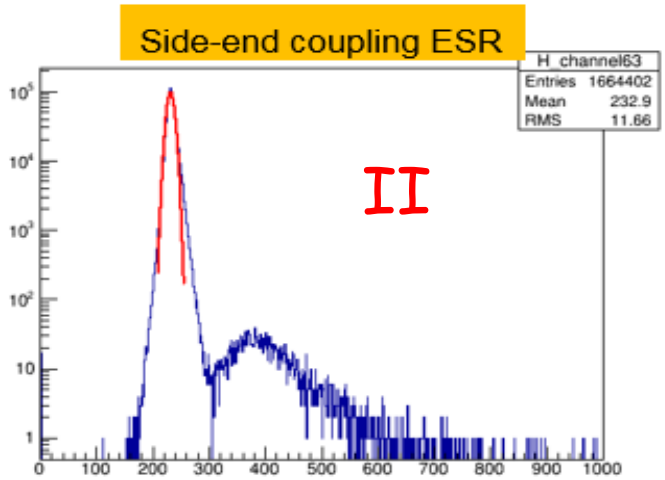


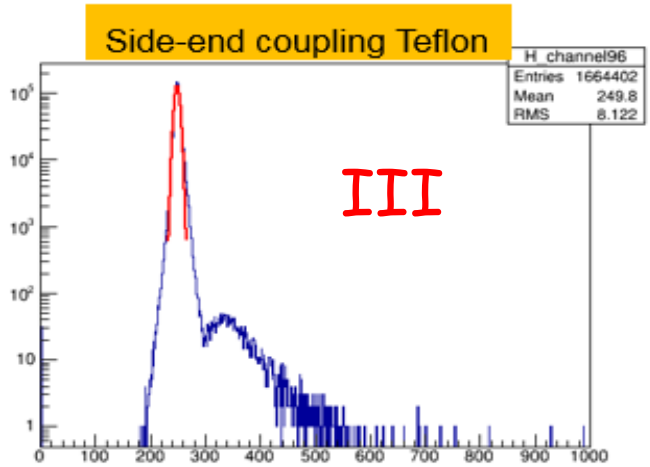


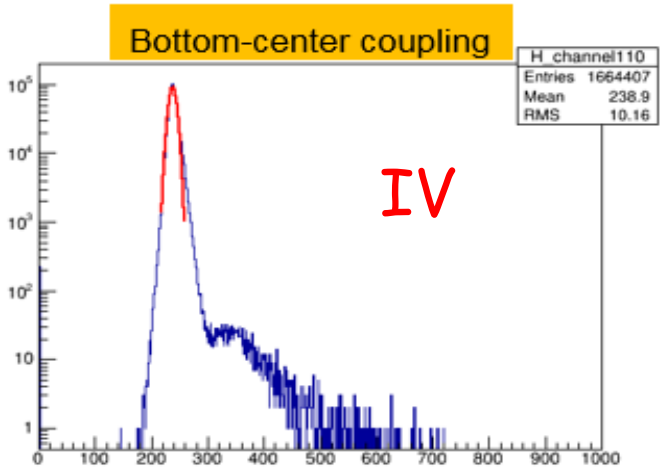


Single Layer Prototype









Outline

- Motivation
- CEPC ECAL
  - Sensitive Detector
  - Electronics
- Test Results
  - Single layer prototype assembling
  - Beam test
- Summary

Summary

- Optimized ECAL absorber thickness, active layers and cell size
- Improved uniformity of scintillator strip light output
- Achieved SiPM response function for nonlinearity correction
- The electronics boards were designed based-on SPIROC chip
- Assembled single layer prototype and obtained preliminary cosmic ray test results

Summary

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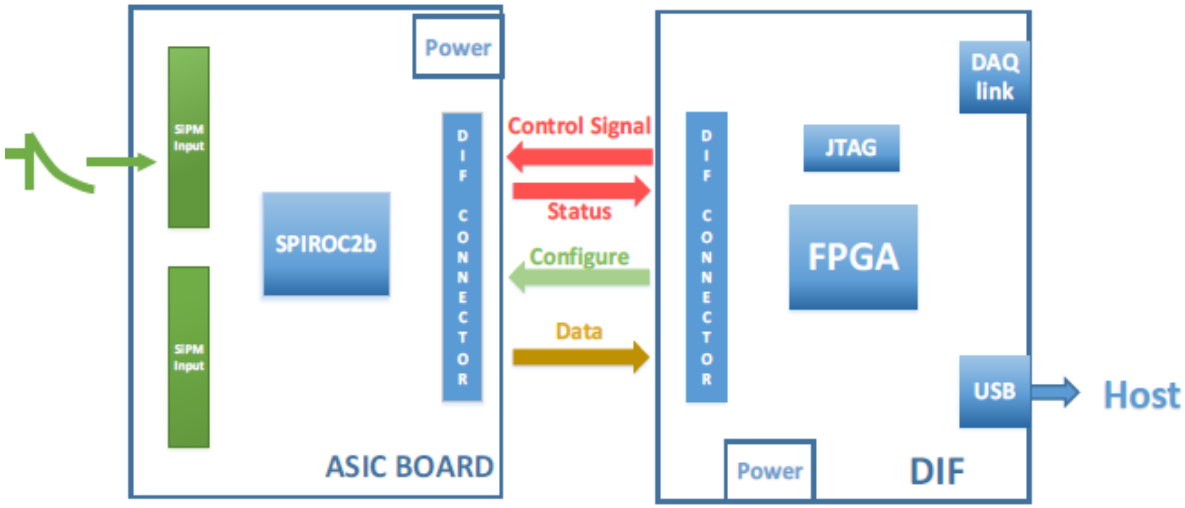
Thanks

Backup

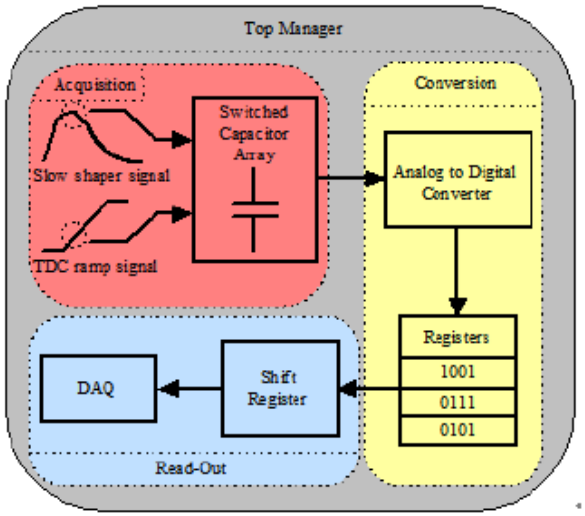
Readout Electronics

- SiPM front-end with **ASIC SPIROC2b/SPIROC2e** of 36 channels
- **FPGA** (Artix-7 200T)
- DIF is **compatible for further FEB**
- USB for data upload & cmd sending
- USB for single DIF, and **serial port for DAQ** when using multiple DIF

- Switched capacitor array store charge measurement
- 12 bits ADC conversion
- Variable Gain due to:
  - adjustable C_f of pre-amplifer
  - R_{load} on the board
  - Shaping time and delay



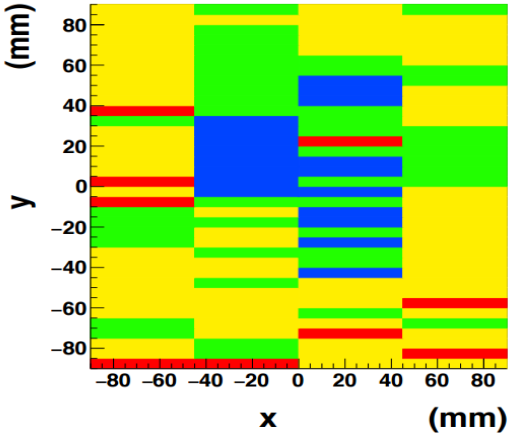
System schematic



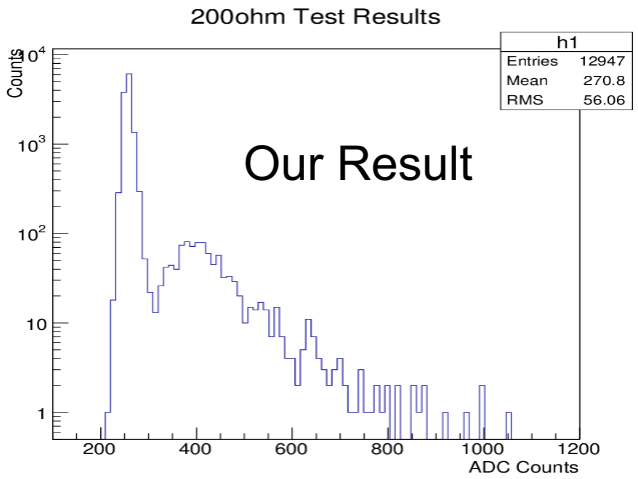
ASIC High level diagram

Test Results

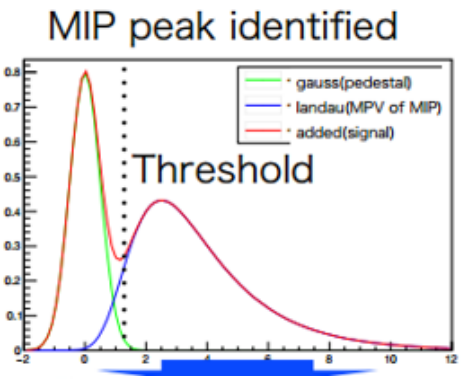
- Compared with CALICE-EBU ECAL

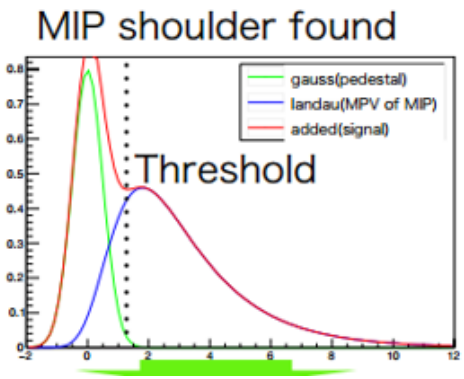


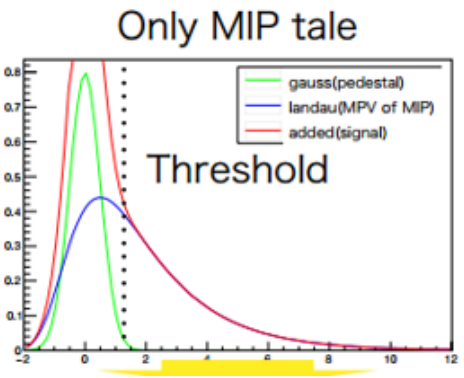
- MIP peak identified
  - 18 ch (12.5%)
- Shoulder found
  - 45 ch (31.25%)
- Tale only
  - 72 ch (50.00%)
- Dead or noisy channel
  - 9 ch (6.25%)



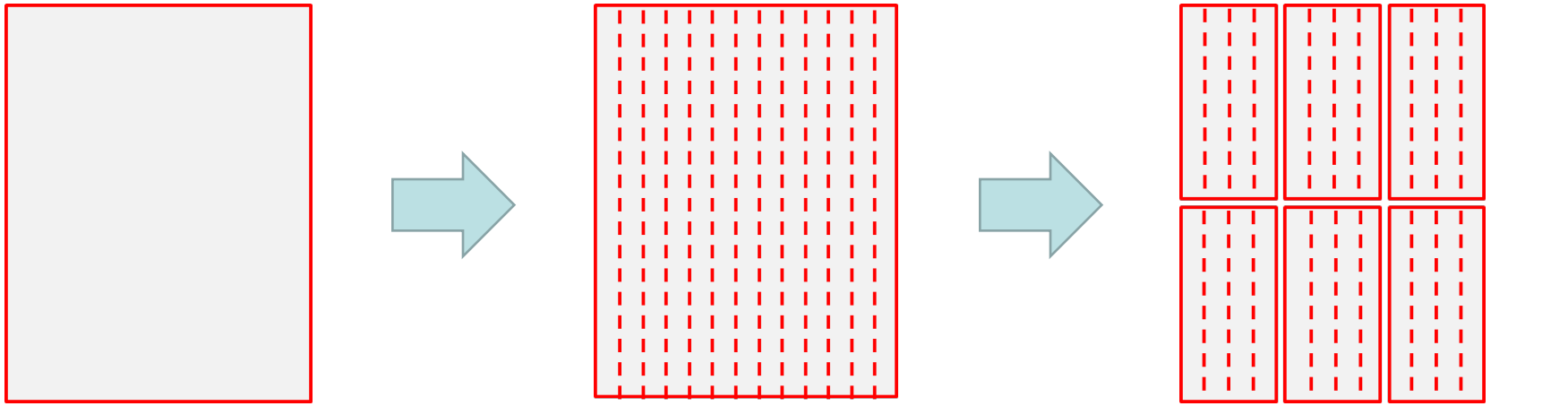
- Peak identified channels are only 12.5%.
  MIP peak identification with 10k pixel MPPC is not easy.







CALICE-EBU ECAL Results



A schematic showing the cutting of ESR and assembling of scintillators

- ESR反射层的规模化分割技术非常成熟，产能和效率非常高，无技术瓶颈